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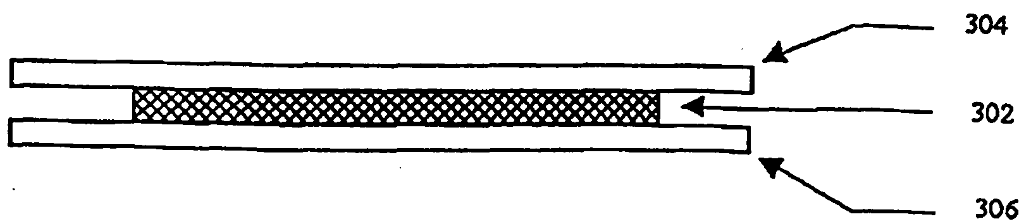


(57) Abstract

A susceptor composition that can bond two or more layers or substrates to one another and that can be used to coat a cut substrate. The susceptor composition is activated in the presence of radio frequency (RF) energy. In one embodiment, the susceptor composition of the present invention comprises a susceptor and a carrier. The carrier and susceptor are blended with one another and form a mixture, preferably a uniform mixture. The susceptor is present in an amount effective to allow the susceptor composition to be heated by RF energy. In a preferred embodiment, the susceptor also functions as an adhesive. The susceptor is an ionic or polar compound and acts as either a charge-carrying or an oscillating/vibrating component of the susceptor composition. The susceptor generates thermal energy in the presence of an RF electromagnetic or electrical field (hereafter RF field). According to the present invention, the susceptor can be an inorganic salt (or its respective hydrate), such as stannous chloride ($SnCl_2$) or lithium perchlorate ($LiClO_4$), or an organic salt, such as lithium acetate ($LiC_2H_3O_2$). The susceptor can be a non-ferromagnetic ionic salt. The susceptor can also be a polymeric ionic compound ("ionomer") which preferably also functions as an adhesive and/or coating. Under RF power levels of about 0.5 kilowatt (kW) to 1kW, and frequencies of about 1 to 100 MHz, the susceptor composition of the present invention facilitates the bonding of single layers of polymeric materials such as polyolefins, non-polyolefins, and non-polymeric materials, as well as multilayer stacks of these materials.

# RF Active Compositions for Use in Adhesion, Bonding and Coating

## *Background of the Invention*

### *Field of the Invention*

This invention relates generally to the use of media containing ionic compounds and/or nonionic compounds with high dipole moments as a radio frequency (RF) susceptors in RF activated systems.

### *Related Art*

Radio frequency (RF) heating is a well established non-contact precision heating method that is used to generate heat directly within RF susceptors, and indirectly within materials that are in thermally conductive contact with RF susceptors. RF susceptors are materials that have the ability to couple and convert RF energy into heat energy within the material.

Conventional adhesives are not suitable RF susceptors that can be directly heated and activated by RF heating. Rather, these conventional adhesives are typically heated indirectly through thermally conductive contact with an RF susceptor material. FIG. 1 illustrates two conventional methods that are currently used in industry for indirect RF heating of conventional adhesives: The first method is illustrated in FIG. 1A, where susceptor material 102 exists as a bulk macroscopic layer. RF susceptor material 102 is directly heated by RF energy, and adhesive layer 104 is indirectly heated through thermally conductive contact with RF susceptor material 102. For example, adhesive layer 104 may be applied to a continuous surface of susceptor material 102, such as steel or aluminum. The second method is illustrated in FIG. 1B, where susceptor material 112 consists of discrete macroscopic particles. Adhesive layer 114 is loaded with macroscopic

particles of a RF susceptor material 112, such as macroscopic particles or flakes of metal oxides, metallic alloys, or aluminum. With this conventional method, each RF susceptor particle 112 acts as a discrete RF susceptor, generating heat throughout adhesive layer 114.

An example of a conventional RF energy activated composition, such as that shown in FIG. 1B, is described in U.S. Patent No. 5,378,879, issued to Monovoukas ("Monovoukas"). Monovoukas utilizes macroscopic "loading particles" as discrete RF susceptors. The particles are heated by RF energy and in turn conduct heat to the surroundings. These macroscopic loading particles are thin flakes (i.e. in thin disk-like configuration) that are designed to be admixed to relatively thick extruded materials. However, these flakes are not well suited for use as susceptors in thin film bonding applications in which physical distortions, discolorations in the surface, or opacity of the bonded films would result from the flakes.

Another example of a conventional inductively activated adhesive is described in U.S. Patent No. 3,574,031, issued to Heller *et al.* ("Heller"). Heller describes a method of heat welding thermoplastic bodies using an adhesive layer that contains uniformly dispersed macroscopic RF susceptors, typically iron oxide particles. These discrete RF susceptor particles are ferromagnetic in nature. A disadvantage of this type of method is that a tradeoff must be made between the size of the particle employed versus the power level and duration of the inductive heating process. For example, if susceptor particles are kept small in size, the mechanical strength of the bond tends to increase. However, as the size of these discrete susceptors is reduced, the power levels and dwell times required to heat the RF susceptor material and achieve acceptable bonds tend to increase. Another disadvantage of this type of method is the high levels of loading of the medium with RF susceptor particles that is required for efficient activation. Such high loading levels detract from the physical properties and rheology of the adhesive composition. Still another disadvantage is the dark color and opacity of the composition, which renders the composition undesirable for many applications.

An example of adhesive activated by a dielectric process is described in U.S. Patent No. 5,661,201, issued to Degrand ("Degrand"). Degrand describes a thermoplastic film including at least one ethylene copolymer and a sufficient quantity of N,N-ethylene-bisstearamide that is capable of being sealed utilizing a current at a frequency of about 27.12 megahertz (MHz). A disadvantage of this type of film and sealing process is the inherent tendency to also heat the adherand.

U.S. Patent No. 5,182,134, issued to Sato, discloses methods of curing a thermoset composition by applying an RF signal having a frequency of about 1 to 100 MHz to a composition comprising a major portion of a thermoset and a receptor. The receptor is described as being one of the alkali or alkaline earth metal sulfate salts (e.g. calcium sulfate), aluminum trihydrate, quaternary ammonium salts, phosphonate compounds, phosphate compounds, polystyrene sulfonate sodium salts or mixtures thereof. According to this patent, all of the exemplified compositions took longer than one second to heat.

U.S. Patent No. 5,328,539, issued to Sato, discloses methods of heating thermoplastic susceptor compositions by applying an RF signal having a frequency of about 1 to 100 MHz. The susceptors are described as being one of the alkali or alkaline earth metal sulfate salts (e.g. calcium sulfate), aluminum trihydrate, quaternary ammonium salts, phosphonate compounds, phosphate compounds, polystyrene sulfonate sodium salts or mixtures thereof. According to this patent, all of the exemplified compositions took longer than one second to heat.

U.S. Patent No. 4,360,607, issued to Thorsrud, discloses a composition suitable for sensitizing thermoplastic compositions to the heating effects of microwave energy comprising (1) an alcohol amine or derivative thereof, (2) a simple or polymeric alkylene glycol or derivative thereof, (3) silica and, optionally, (4) a plasticizer.

What is needed is a composition (e.g. adhesive composition or coating) containing either dissolved or finely dispersed susceptor constituents that are preferably colorless or of low color. Further, the composition should be transparent or translucent throughout an adhesive matrix or plastic layer. This type of RF susceptor will result in more direct and uniform heating throughout an

adhesive matrix or plastic layer. Further, it is desirable that such a composition will allow bonding with no physical distortion or discoloration in the bonded region of thin films. Still another desirable feature is activation of the RF susceptors at frequencies, e.g. of about 15 MHz or below, most preferably about 13.5 MHz, which are more economical to generate than higher frequencies and do not substantially heat dielectric substrates. A further desirable feature is that the composition can be activated or melted in less than one second. It is also desirable to have a formulation which may be optimized for a particular application, such as cutting, coating, or bonding substrates.

## *Summary of the Invention*

The present invention generally relates to the creation and use of a composition (also referred to as a "susceptor composition") that can bond two or more layers or substrates to one another and that can be used to coat or cut a substrate. The susceptor composition is activated in the presence of radio frequency (RF) energy.

In one embodiment, the susceptor composition of the present invention comprises a susceptor and a carrier. The carrier and susceptor are blended with one another and form a mixture, preferably a substantially uniform mixture. The susceptor is present in an amount effective to allow the susceptor composition to be heated by RF energy. In a preferred embodiment, the susceptor also functions as an adhesive or coating.

In another embodiment of the present invention, the susceptor composition further comprises an adhesive compound. The adhesive compound, susceptor, and carrier are blended with one another to form a mixture that is activated in the presence of RF energy. Preferably, the mixture is substantially uniform.

In another embodiment of the present invention, the susceptor composition further comprises at least one of a thermoplastic polymer, thermoset resin, elastomer, plasticizer, filler or other material. The additive, susceptor, and carrier

are blended with one another to form a mixture that is activated in the presence of RF energy.

In yet another embodiment of the present invention, the composition can further comprise a second carrier that is an insoluble porous carrier that is saturated with the composition.

The susceptor is an ionic or polar compound and acts as either a charge-carrying or an oscillating/vibrating component of the susceptor composition. The susceptor generates thermal energy in the presence of an RF electromagnetic or electrical field (hereafter RF field). According to the present invention, the susceptor can be an inorganic salt (or its respective hydrate), such as stannous chloride ($SnCl_2$), zinc chloride ($ZnCl_2$) or other zinc salt, or lithium perchlorate ($LiClO_4$), or an organic salt, such as lithium acetate ($LiC_2H_3O_2$). The susceptor can be a non-ferromagnetic ionic salt. The susceptor can also be a polymeric ionic compound ("ionomer") which preferably also functions as an adhesive or coating. Under RF power levels of about .05 kilowatt (kW) to 1 kW, and frequencies of about 1 to 100 MHz, the susceptor composition of the present invention facilitates (a) the bonding of single layers of polymeric materials such as polyolefins, non-polyolefins, and non-polymeric materials, paper?? as well as multilayer stacks of these materials, and (b) coating on a substrate such as a printed pattern on plastic films, metallic foils, etc.

Surprisingly, it has been discovered that when an ionomer is combined with a polar carrier, much more heating occurs when exposed to RF energy than when the ionomer or carrier is exposed separately to RF energy.

According to another embodiment of the present invention, a method of bonding a first material or substrate to a second material or substrate comprises interposing a composition according to the invention between the first and second materials and applying RF energy to the composition to heat the composition, thereby causing the first and second materials to become bonded. In one embodiment, the composition comprises a susceptor and a carrier that are distributed in one another to form a mixture, preferably, a substantially uniform mixture. Optionally, the composition may further comprise other compounds and

additives as described herein. The susceptor is present in the composition in an amount effective to allow the composition to be heated by RF energy.

According to another embodiment of the present invention, a method of bonding or adhering a first substrate to a second substrate includes: applying a first composition onto the first substrate; applying a second composition onto the second substrate; contacting the first composition with the second composition; applying RF energy to the first and second compositions to heat the compositions, thereby causing the first and second substrates to become adhered or bonded; wherein one of the compositions comprises a susceptor and the other of the susceptors is a polar carrier, and the susceptor and/or the carrier are present in amounts effective to allow the first and second compositions to be heated by RF energy.

According to yet another embodiment of the present invention, a method of bonding or adhering a first substrate to a second substrate includes: applying a first composition onto the first substrate; applying a second composition onto the first composition; contacting the second substrate with the second composition; and applying RF energy to the first and second compositions to heat the compositions, thereby causing the first and second substrates to become adhered or bonded, wherein one of the compositions comprises a susceptor and the other of the compositions is a polar carrier, and the susceptor and/or the carrier are present in amounts effective to allow the first and second compositions to be heated by RF energy.

According to another embodiment of the present invention, a method of making a susceptor composition comprises admixing a susceptor and a carrier, wherein, preferably, the carrier and susceptor are substantially uniformly dispersed in one another and form a uniform mixture. The susceptor and/or carrier are present in the composition in an amount effective to allow the susceptor composition to be heated by RF energy.

According to a further embodiment of the present invention, an adhered or a bonded composition can be obtained according to the disclosed methods.

According to a further embodiment of the present invention, a kit for bonding a first material to a second material comprises one or more containers, wherein a first container contains a composition comprising a susceptor and a carrier that are dispersed in one another and form a mixture. The kit may also contain an adhesive or elastomeric compound or other additives as disclosed herein. The susceptor and/or carrier are present in an amount effective to allow the composition to be heated by radio frequency energy.

According to a further embodiment of the present invention, a kit for adhering or bonding a first substrate to a second substrate, comprises at least two containers, wherein one of the containers comprises a susceptor and another of the containers comprises a polar carrier, wherein when the susceptor and the carrier are applied to substrates and the susceptor and carrier are interfaced, a composition is formed that is heatable by RF energy.

The invention also relates to a composition comprising an ionomeric polymer and a polar carrier.

The invention also relates to a method of curing a thermoset resin, comprising combining the thermoset resin with a polar carrier to give a mixture and exposing the mixture to RF energy.

The invention relates to an apparatus, having: a first portion having a first mating surface; a second portion, having a second mating surface; a composition disposed between the first mating surface and the second mating surface, wherein the composition comprises a susceptor and a polar carrier wherein the susceptor and/or the polar carrier are present in amounts effective to allow the composition to be heated by RF energy, and wherein the composition adheres the first mating surface to the second mating surface such that application of a force to separate the first mating surface and the second mating surface results in breakage of the apparatus unless the composition is in a melted state.

The invention also relates to a method of applying a protective film or printed image/ink on a substrate.

The invention also relates to a method for dynamically bonding a first adherand to a second adherand. The method includes: (1) creating an article of

manufacture comprising the first adherand, the second adherand, and a composition, the composition being between the first adherand and the second adherand, wherein the composition can be activated in the presence of an RF field; (2) moving the article of manufacture along a predetermined path; (3) generating along a portion of the predetermined path an RF field having sufficient energy to activate the composition, wherein the composition is activated by its less than one second exposure to the RF field.

The invention also relates to a method for applying a susceptor composition to a substrate. In one embodiment, the method includes: (1) formulating the susceptor composition as a liquid dispersion; (2) applying the liquid dispersion of the susceptor composition to the substrate; (3) drying the susceptor composition, wherein the drying step includes the step of applying RF energy across the composition, thereby generating heat within the liquid dispersion. In a preferred embodiment, one may roll up the substrate after the susceptor composition has dried.

The invention also relates to a method for cutting a substrate. The method includes: (1) applying a composition to a portion of the substrate, wherein the composition comprises a susceptor and polar carrier wherein the susceptor and/or said polar carrier are present in amounts effective to allow the composition to be heated by RF energy, and wherein the portion of the substrate defines a first section of the substrate and a second section of the substrate; (2) melting the portion of the substrate by heating the composition via RF energy; and (3) after the portion of the substrate has begun to melt, applying a force to the substrate to separate the first section from the second section.

The method also relates to a method of dynamically bonding a first substrate to a second substrate. The method including: applying a composition onto the first substrate; after applying the composition onto the first substrate, forming a roll of the first substrate; storing the roll; unrolling the roll; and while unrolling the roll: joining an unrolled portion of the first substrate with a portion of the second substrate such that the portion of the second substrate is in contact with a portion of the composition applied onto the first substrate; and applying RF

energy to the portion of the composition, wherein the portion of the composition heats and melts as a result of the RF energy being applied thereto.

Further features and advantages of the present invention, as well as the structure and operation of various embodiments of the present invention, are described in detail below with reference to the accompanying drawings.

## *Brief Description of the Drawings*

The present invention is described with reference to the accompanying drawings. In the drawings, like reference numbers indicate identical or functionally similar elements. Additionally, the left-most digit(s) of a reference number identifies the drawing in which the reference number first appears.

FIGs. 1A and 1B illustrate conventional schemes for inductively heating adhesives.

FIG. 2 shows an RF active composition according to the present invention.

FIG. 3 shows a susceptor composition placed between two polyolefin layers to be attached according to the present invention.

FIG. 4 illustrates a block diagram of an RF heating system according to a first embodiment.

FIG. 5 illustrates a block diagram of a heating system according to a second embodiment.

FIG. 6 illustrates a two probe heating system.

FIGS. 7A and 7B further illustrate the two probe heating system.

FIG. 8 illustrates one embodiment of an alternating voltage supply.

FIG. 9 is a flow chart illustrating a process for heating a composition according to the present invention.

FIG. 10 further illustrates one embodiment of an impedance matching circuit.

FIG. 11 shows a method of bonding adherents using a composition that is activated in the presence of RF energy.

FIGS. 12 to 17 illustrate additional embodiments of probes 602 and 604.

FIG. 18 illustrates one embodiment of an application system for applying a composition according to the present invention to a substrate.

FIG. 19 illustrates one embodiment of a system for bonding or adhering various adherents.

FIGS. 20A and 20B illustrates a static bonding system for bonding adherents.

FIG. 21 illustrates an in-line bonding system.

FIG. 22 further illustrates one embodiment of the in-line bonding system illustrated in FIG. 21.

FIGS. 23-27 illustrate alternative designs of the in-line bonding system illustrated in FIG. 21.

FIGS. 28A and 28B illustrate one embodiment of a system for the manufacture of flexible packaging material.

FIG. 29 further illustrates film 2815.

FIG. 30 illustrates one embodiment of film 2870.

FIG. 31 illustrates an alternative system for manufacturing an RF activated adhesive film for use in the flexible packaging industry.

FIG. 32 illustrates a conventional aseptic package material construction.

FIG. 33 illustrates an aseptic package material according to one embodiment that does not include metallic foil.

FIG. 34 illustrates another embodiment of an aseptic packaging material construction that does not use metallic foils.

FIG. 35 illustrates a conventional cap sealing construction.

FIG. 36 illustrates a seal, according to one embodiment, for sealing a bottle.

FIG. 37 illustrates a design for adhering a flexible bag to an outer box.

FIG. 38 illustrates a step and repeat manufacturing system.

FIG. 39 illustrates an index table bonding system.

FIG. 40 shows an example experimental set-up utilized to test compositions according to the present invention.

FIG. 41 illustrates another experimental set-up for testing compositions according to the present invention.

FIG. 42 illustrates test probes.

FIG. 43 illustrates a process for assembling a book, magazine, or periodical, or the like.

FIG. 44 illustrates a paper substrate coated with a susceptor composition.

FIG. 45 illustrates a stack of coated paper substrates.

FIGS. 46 and 47 illustrates one embodiment of an envelope or mailer according to the present invention.

FIG. 48 illustrates a cross-section of a container sealed with a susceptor composition of the present invention.

FIG. 49 illustrates another example of a device sealed or otherwise joined together with a composition of the present invention.

FIG. 50 shows another example of a device sealed or otherwise joined together with a composition of the present invention.

FIG. 51 illustrates still another example of a cross-section of a container 5100 that has been sealed with the adhesive of the present invention.

FIG. 52 illustrates a system for bonding two substrates.

FIG. 53 illustrates another embodiment of a system for bonding two substrates.

## *Detailed Description of the Preferred Embodiments*

## *I. Overview and Discussion of the Invention*

The present invention is directed towards an RF susceptor composition and methods and systems of bonding, cutting, and/or coating substrates and surfaces using the susceptor composition. The susceptor composition is a mixture of RF susceptors and/or adhesive/coating compounds and/or other additives dissolved or finely dispersed in a matrix. Preferably, the RF susceptors and/or adhesive compounds and/or other additives are uniformly dissolved or finely dispersed in the matrix. The susceptor composition is capable of coupling efficiently in an RF field having a frequency of about 15MHz or below. In order to be useful in industry and commercial products, a susceptor composition preferably has the following characteristics: (1) an activation time in the presence of a low power RF field on the order of 1 second or less, (2) adequate bond or adhesive strength for the intended use, (3) transparency or translucency and only slight coloration (if any), (4) minimal distortion of the substrates being attached, and (5) on demand bonding of preapplied adhesive. Further, it is desirable that the susceptor composition have coupling ability in the absence of volatile solvents, although the presence of nonvolatile liquids (such as plasticizers) may be desirable. These characteristics are important in providing sufficient heat transfer to the substrates or layers to be bonded to one another, or for adhesion to take place at the interface. Additionally, the susceptor composition should not interfere with the thermal bonding or inherent adhesive properties of the substrates or layers to be bonded or adhered to one another.

According to the present invention, a susceptor composition used to bond or adhere substrates or layers can be directly heated by exposure to an RF field having frequencies ranging from 1 - 100 MHz. The susceptor composition comprises a susceptor, and a carrier blended with one another to form a mixture. In addition, the susceptor composition can further comprise one or more adhesive compounds blended with the susceptor and carrier to form the mixture.

Susceptors are either ionic or polar compounds introduced as a component of a composition, such that RF heating of the resulting susceptor composition occurs. An ionic susceptor is an ionic compound introduced as a sufficiently charge-carrying or oscillating component of the composition. A polar susceptor

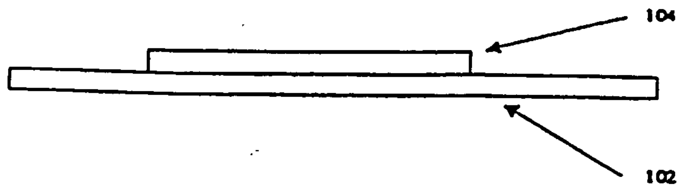


FIG 1A

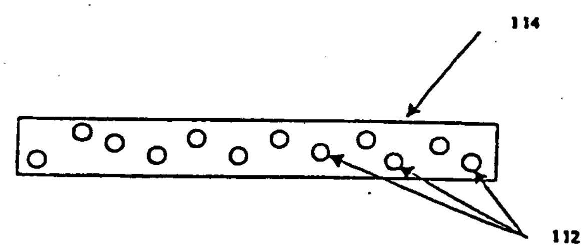


FIG. 1B

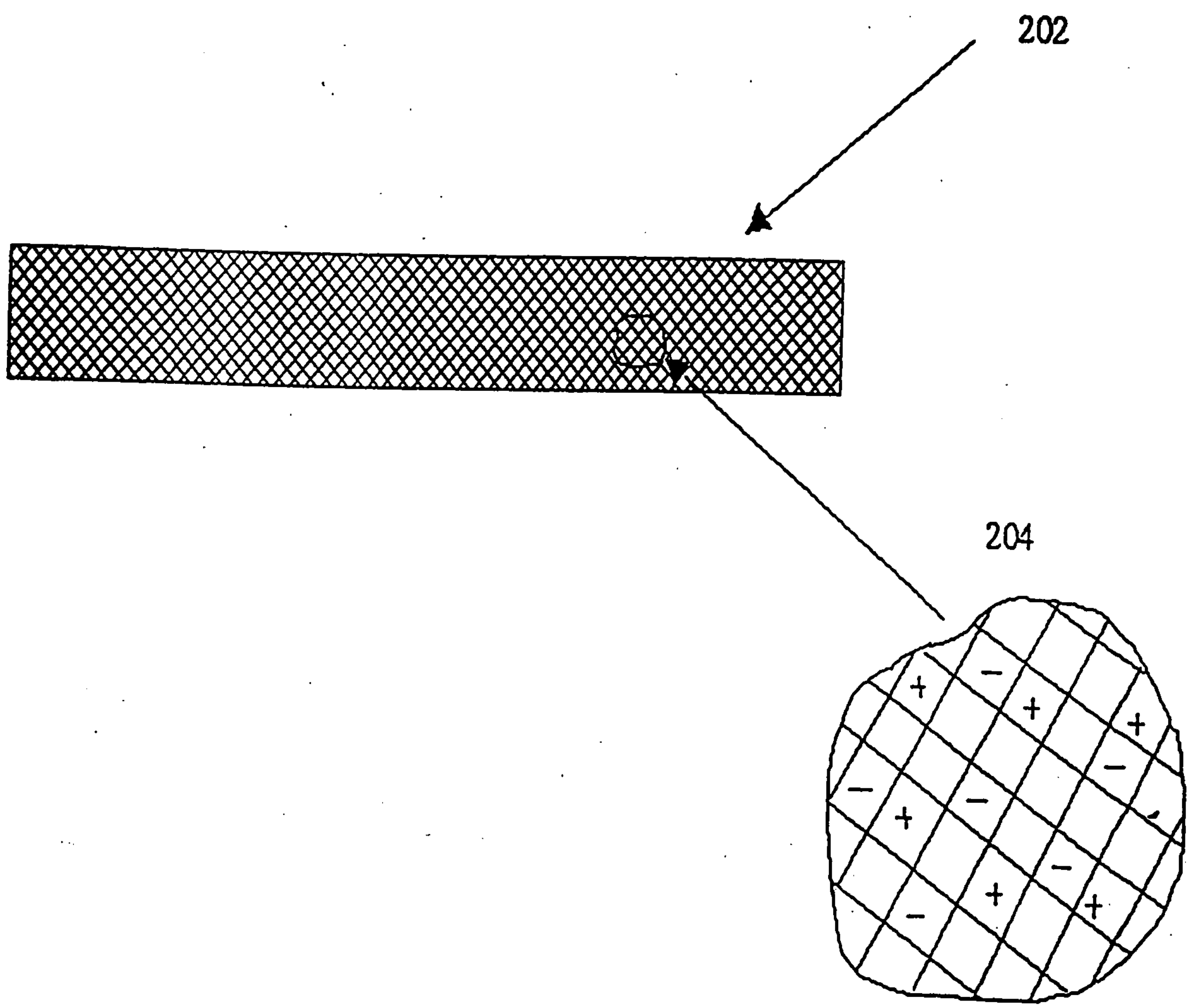


FIG. 2

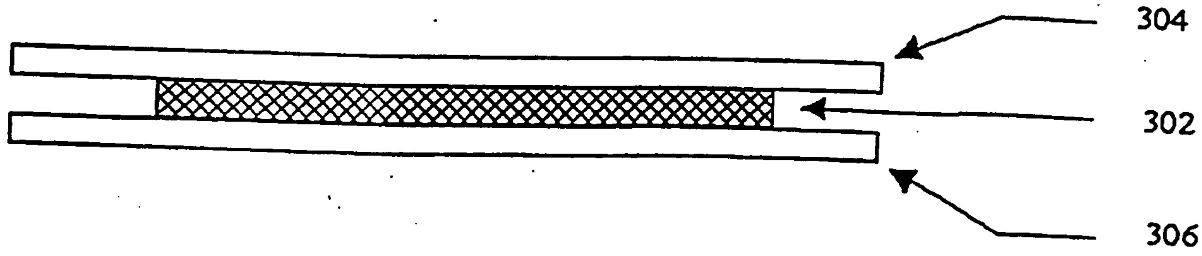


FIG. 3

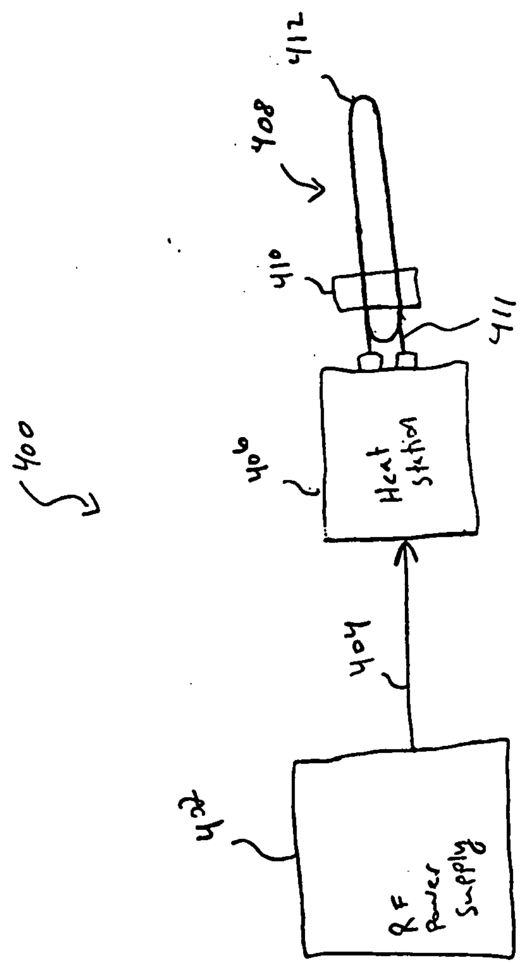


FIG. 4

*What Is Claimed Is:*

1. A composition for use in adhesion or bonding, comprising:

a susceptor; and (ionic compound) or polar compound or ionomer

a polar carrier,

wherein said susceptor and/or said polar carrier are present in amounts effective to allow said composition to be heated by radio frequency (RF) energy, with the proviso that said susceptor is not a quaternary ammonium salt.

2. A composition for use in coating, comprising:

a susceptor; and

a polar carrier,

wherein said susceptor and/or said polar carrier are present in amounts effective to allow said composition to be heated by RF energy, with the proviso that said susceptor is not a quaternary ammonium salt.

3. A composition for use in adhesion, bonding or coating, consisting essentially of:

a susceptor; and

a polar carrier,

wherein said susceptor and/or said carrier are present in amounts effective to allow said composition to be heated by RF energy.

4. The composition of any one of claims 1-3, wherein the susceptor and the carrier are substantially blended with one another and form a mixture.

5. The composition of any one of claims 1-3, wherein the susceptor and the carrier are disposed on one another.

6. The composition of any one of claims 1-3, wherein the susceptor is an ionic compound.

7. The composition of any one of claims 1-3, wherein the susceptor is a polar compound having a sufficiently high dipole moment that molecular oscillations or vibrations of the compound occur when exposed to RF energy.

8. The composition of any one of claims 1-3, further comprising or consisting essentially of an adhesive compound, wherein said adhesive compound, said susceptor and said polar carrier are blended substantially with one another to form said mixture.

9. The composition of claim 8, wherein said adhesive compound and said susceptor are an ionomer.

10. The composition of claim 8, wherein said adhesive compound is polyvinylpyrrolidone (PVP) in a concentration of from about 10 (weight) % to about 35% and said polar carrier is N-methylpyrrolidone (NMP) in a concentration of from about 1% to about 60%.

11. The composition of claim 8, wherein said adhesive compound is PVP/vinyl acetate copolymer in a concentration of from about 10% to about 35% and said polar carrier is NMP in a concentration of from about 1% to about 60%.

12. The composition of claim 8, wherein said adhesive compound comprises or consists essentially of an aqueous dispersion of a branched polyester adhesive.

13. The composition of claim 12, wherein said branched polyester adhesive is present in a concentration from about 25% to about 75%.

14. The composition of claim 12, wherein said susceptor comprises or consists essentially of an ionic salt incorporated into the aqueous dispersion.